REMARKS

In the Office Action, claims 7-10 were withdrawn from consideration by the Examiner as being directed to a non-elected invention as stated in the Office Action. Applicant notes the previously proposed drawing corrections are approved and new corrected drawings will be filed in due course.

The substitute specification and the abstract were objected to because of a failure to submit the marked-up versions. The substitute specification contains no new matter. The substitute specification meets the formal objections. The marked-up versions are enclosed herewith. Accordingly, it is believed that the substitute specification and abstract should be entered.

Claims 1-6 were rejected under 35 USC 112, first paragraph, as containing subject matter which was not described adequately in the specification as set forth in the Office Action. Claims 1-6 were rejected under 35 USC 112, second paragraph as being indefinite for the reasons stated in the Office Action.

Claims 1-6 were rejected under 35 USC 102(b) as anticipated by Kobayashi et al US 5,853,328 on the grounds set forth in the Office Action. Claims 4-6 were rejected under 35 USC 102(b) as anticipated by Parker, US 2,124,006 for the reasons stated in the Office Action. Claims 4-6 were rejected under 35 USC 102(b) as anticipated by Hendrickson, US 1,149,762 on the grounds set forth in the Office Action. Claims 1-6 were rejected under 35 USC 102(e) as anticipated by Pritschow et al, US 5,916,328 for the reasons stated in the Office Action. Claims 1-6 were rejected under 35 USC 102(a) as anticipated by Chinzei et al, "MR Compatible Surgical Assist Robot" on the grounds set forth in the Office Action.

Reconsideration of these rejections is requested in view of the amendment and the argument herein.

In the matter of the restriction requirement applied to the newly submitted claims 7-10, the position of the Examiner is not fully understood. The Examiner's rationale is based on a possible use of the product of claims 1-6 which differs from the use of the method of claims 7-10. The Examiner is correct in his suggestion of torque transmission. In fact, there may be further uses such as the stirring of liquid food products, as a hammer for banging on a drum to make music, and as prop in a teaching of mechanical engineering.

It appears that the Examiner has not considered the use and function of the device of claims 1-6 that is actually set forth in the preambles of the claims 1 and 4, namely, to establish the position of a bearing, and to establish the direction of an arm segment extending from the bearing. The preambles of claims 7 and 9 teach establishment of the position of a bearing, and the establishment of the direction of an arm segment extending from the bearing. Clearly the preambles of claims 1 and 4 are in agreement with the preambles of claims 7 and 9.

Upon comparing the second paragraphs of the foregoing claims, it is noted that they agree with respect to the attachment of bearings to a rod, and that the bearings can change their relative positions. The third paragraphs of the foregoing claims similarly agree on the teaching of motion and of travel of the bearings.

With so much agreement set forth in the claims, it appears to be unfair to suggest uses outside of the teachings of the claims to

defeat the unity of invention which appears to be present, based on a reading of the claims. Reconsideration of the restriction and of the action of withdrawal of the claims is requested.

In the matter of the rejections of the claims under 35 USC 112, first and second paragraphs, the claims have been amended to restore much of the previous wording of the claims. This is believed to meet points raised by the Examiner. Also the claims have been edited to set forth both apparatus and method aspects of the invention. In the event that the Examiner maintains the status of withdrawal of claims 7-10, possibly the Examiner will regard all of claims 1-6, including both the method and the apparatus claims, as being directed to the same invention.

With respect to the rejections under 35 USC 102, the following argument is presented to overcome these rejections to secure allowance of the claims.

The present invention relates to link mechanism for determining the position (X_1, Y_1, Z_1,) and the direction(angles θ, ϕ) of the axial rod R by giving the bearing or support P1 the positions X_1, Y_1 and Z_1, and the bearing or support P2 the position X_2, Y_2 and Z_2. The object to be determined the position and direction is the axial rod R_1 neither P1 nor P2. The bearing or supports (P_1, P_2) support the axial rod R which are not supported by the axial rod.

The relation between relative position $X' = (X_2 - X_1)$, $Y' = (Y_2 - Y_1)$, and $Z' = (Z_2 - Z_1)$, and angle θ, ϕ is derived from the solution of following equations.

$X' = \gamma \cos \phi \sin \theta$

$y' = \gamma \sin \phi \sin \theta$

$Z' = \gamma \cos \theta$

Therefor, by locating P_1 into new position X_1 Y_1 Z_1, end locating P_2 into new position X_2 Y_2 Z_2 the new position X_1 Y_1 Z_1 and new angle θ, ϕ of the axial rod are realized. To achieve this movement of the axial rod, the link mechanism 1 constructed as below.

The representative three-dimensional coordinates (x y z) of the whole link mechanism 1 (i.e. axial rod R) are determined from the position of the spherical bearing P_1 driven by the driver, and at the same time, the direction (angles θ and ϕ,) of the axial rod R is determined from a motion of the spherical bearing P_2 driven by the driver relative to the spherical bearing P_1. The axial rod R is fixed to the inner wheel 2 or outer wheel 3 of the spherical bearing P_1 12. Thus the direction (angles θ and ϕ) of the axial rod R is determined from a motion of the spherical bearing or support P_1 and P_2. The spherical bearings P_1 and P_2 are driven by drivers (not shown) passively.

This mechanism can be used in a robot to determine the position and direction of the robot arm, as a example.

(1) The most distinctive feature of the present invention is that, its input is the positioning of the two supports (e.g., spherical bearings) and the output is the position and direction of the said axial rod. While, the previous arts pointed out by the Office Action were either of

1) a rod is used to constrain position and/or motion of spherical bearings, in other words, the output is the position and/or motion of the bearings (5,853,328, and 1,149,762)

2) a rod is used to as an output, however it is not to define its position and direction rather to stabilize the rod (JP61-201918),

3) the position of a rod is not used as an output directly (4,806,068).

Thus, each, of cited documents neither discloses nor suggests the method and mechanism of the present invention. Next, follows discussions of the respective references.

(2) Kobayashi relates to a power transmission device and a constant velocity universal joint to absorb vibration or movement of the engine of the automobile. Though Kobayashi has a inner and outer member which are movable axially relatively to each other, Kobayashi does not have two spherical bearings which can travel, the motion of one of which relatives to said axial rod along the axis is constrained, and the other of which can travel along said axial rod.

(3) Miyake relates to bearing apparatus having rotating axis and two bearings supporting the rotating axis on the both end of it. Two bearings can not travel. The rotating axis of Miyake should be held in the fixed its home position as its native function and it is not the object to travel and determine its position and direction.

(4) Tampier relates to a transmission mechanism having rotating axis and two bearings supporting the rotating axis on the both end of it. Two bearings can not travel. The rotating axis of Tampier should be held in the fixed its home position as its native function and it is not the object to travel and determine its position and direction.

bearings 24 can not travel. The shaft of Kohli et al should be held In the fixed its home position as its native function and it is not the object to travel and determine its position and direction.

(6) Parker relates to gage supporting arm system for dial test indicator having an axial rod 24 and two supports 20, 21 and 27. But the supports 20 does not support the axial rod 24 and the axial rod 24 is not the object to travel and determine its position and direction.

(7) Pritschow et al relates to device for moving a body in space having a rod-shaped body and two bearings P,P' wherein one of end points of rod body serves for positioning the rod body in the space and other end point of the rod body determine the orientation of the rod body. But Pritschow does not teach that the position of the bearing P' relatives to the position of the bearing P.

(8) Cited Chinzei et al, "MR Compatible Surgical Robot" had been issued Oct. 11, 2000 after the priority date of the present invention that is 13/01/2000. Applicant relies on the priority date and, accordingly, this reference should not serve as a basis for rejection of the claims.

In the event there are further issues remaining the Examiner is respectfully requested to telephone attorney to reach agreement to expedite issuance of this application.

All of the claims are believed to be allowable in view of the foregoing argument.

Since the present claims set forth the present invention patentably and distinctly, and are not taught by the cited art either taken alone or in combination, this amendment is believed to place this case in condition for allowance and the Examiner is respectfully requested to reconsider the matter, enter this amendment, and to allow all of the claims in this case.

Respectfully submitted,

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CERTIFICATE OF FACSIMILE TRANSMISSION

I hereby certify that the accompanying Amendment Upon Final Rejection and Submission of Formal Drawings are being facsimile transmitted to the Patent and Trademark Office on May 2, 2003.

_____
Signed by Martin A. Farber

Dated: May 2, 2003

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MARKED UP VERSIONS

CHINZEI 09/749,125

LINK MECHANISM TO [DETERME] DETERMINE THE POSITION AND DIRECTION

BACKGROUND OF THE INVENTION

a) Field of the Invention

The present invention is a link mechanism to determine a position and direction in three dimensional space. Such a link mechanism is applicable to determine the position and direction of a surgical assist apparatus, an end effector of a robot (manipulator) or the like.

b) Description of the Related Art

In MR/T (magnetic resonance and therapy), fusion of diagnosis and treatment, it is necessary that the presence and function of a [medial] medical equipment do not generate artifacts (such as noises and ghost) on the image. The mutual influence between a medical equipment and MRI is called MR compatibility.

Surgical assist robots are [promising] expected to be used in MR/T. However, since robot mechanism generally uses many metal components such as steel components, electromagnetic motors, electric sensors and the like, it has been difficult to realize MR compatibility. In particular, the end effector, which is used near [at] to a patient, [are] is required to have a very small magnetic susceptibility and low electrical noise radiation. It is therefore difficult to use a complicated mechanism, active mechanical elements such as motors, and various types of sensors.

Under such restrictions, surgical assist robot for MR/T must realize a mechanism to establish, for a robotic arm segment, [determine] at least the position (x y z orthogonal coordinates) and angles θ and ϕ (measured from the center of a coordinate

axes system as, respectively, azimuth and elevation) to define the direction in [3] three-dimensional space. It is also desired that the end effector is cleanable and sterilizable. The end effector is also required to be simple and compact so as not to [intercept] interrupt the view field and the work area of the surgeon. In addition, the output power of an actuator should be as small as possible to maintain safety.

There are many conventional mechanisms to define the position (in terms of the coordinate axes x y z) and angles θ and ϕ. A typical example of such mechanisms is an arm type robot. The arm type robot uses a number of arm links interconnected by joints.

The arm type robot usually has actuators at the joints, otherwise it employs wire mechanism, shaft, and so on to transmit the driving power. The actuator [is] makes it difficult to maintain MR compatibility, and [cannot maintain] inhibits cleaning and sterilization unless a water-proof process is performed strictly. Since the transmission mechanism is composed from many parts and is mechanically complicated, [the power loss can be significant.] it requires a number of power transmission components so that it is mechanically complicated and a power loss cannot be neglected.

A parallel link mechanism, typically a hexa pod type robot, can be designed to place actuators remotely from the end effector. However, since links are concentrated near to, or at the end effector, the mechanical structure is complicated.

By designing the end effector [being long] to be lengthy, it may be MR compatible, cleanable and sterilizable.

In this case, however, its precision is degraded and stronger actuators are required. Such an end effector can be complicated and bulky, and consequently [intercept] interrupt the view field of the surgeons.

Under such circumstances, [the] a link mechanism to determine the position and angles [have] has long been desired, which mechanism has a high precision of position and angle determination, does not require strong actuators, and is mechanically simple [and easy to] for enabling MR compatibility, cleaning and sterilization.

SUMMARY OF THE INVENTION

The invention has been made [under] to accommodate such circumstances. The object of the present invention is to realize a link mechanism for determining the position and angles for an actuator, which mechanism has a high precision of position and angle determination, does not require strong actuators, and is mechanically simple [and easy] to accommodate MR compatibility, cleaning and sterilization, and in which an end effector does not [intercept] interrupt the field of view of the surgeon.

To achieve the above object, the invented link mechanism has the following features: an axial rod; and two spherical bearings to support the axial rod, the two spherical bearings being capable of changing positions of the links of the mechanism, wherein the motion of one of the two spherical bearings relative to the axial rod along the axis of the rod R is constrained, and the [an]other of the two spherical bearings can travel along the axial rod R.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of an [impremention] implementation of an end effector of a robot, in accordance with a link mechanism based on this invention.

Figure 2 is a front view of the link mechanism of the embodiment.

Figure. 3 is a diagram illustrating the motion of spherical bearings.

Figure. 4 is a diagram showing a relation among the positions and directions of spherical bearings P_1 and P_2 and an axial rod R.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An embodiment of the invention will be described with reference to the accompanying drawings.

In Fig. 1, reference numeral 11 generally represents a robot end effector. A link mechanism of the invention is assembled in this robot end effector 11. The end effector 11 has a pair of elongated arms 12 and 13. This pair of arms 12 and 13 cooperatively maneuver to work on a subject. The base portion 14 of the arm 12 is fixed to the outer wheel [3] 3(1) or the inner wheel [2] 2(1), shown in Figs. 2 and 3, of the spherical bearing P_1 of the link mechanism 1 of this invention to be described later, whereas the base portion 15 of the other arm 13 is fixed to the outer wheel [3] 3(2) or the inner wheel [2] 2(2) of the spherical bearing P_2.

As shown in Figures. 1, 2 and 3, the link mechanism 1 of this invention is composed of two spherical bearings P_1 and P_2

and an axial rod R which is a rigid element interconnecting the spherical bearings P_1 and P_2.

The spherical bearing P_1 travels in three dimensional space (or in a partial space thereof), whereas the position of the spherical bearing P_2 is constrained in three dimensional space or in a two-dimensional plane (or in a partial space or plane thereof) relative to the spherical bearing P_1.

Each of the spherical bearings P_1 and P_2 is composed of the inner wheel [2] 2(1), 2(2) respectively and the outer wheel [3] 3(1), 3(2) respectively. The inner and outer wheels [2] 2(1) and [3] 3(1) of the bearing P_1, and similarly for the bearing P_2, share [the] a common centroid so that they [relatively] rotate relative to each other around this point. It is a common specification of widely available spherical bearings. The axial rod R is fixed to the inner wheel [2] 2(1) or outer wheel [3] 3(1) of the spherical bearing P_1 which wheel is not fixed to the arm 12. The axial rod R is fixed neither to the inner wheel [2] 2(2) nor to the outer wheel [3] 3(2) of the spherical bearing P_2. The spherical bearing P_2 can therefore slide along the axial rod R as [P2] P_2 moves.

This link mechanism 1 can be made of only passive mechanical elements. Although sensors are not essential to determine the position and angles, such sensors may be used.

The spherical bearings P_1 and P_2 are driven by drivers (not shown). Such drivers and a method of determining the positions of the spherical bearings P_1 and P_2 may be any desired drivers and method.

The determination of the position and direction of the axial rod R of the link mechanism 1 constructed as above is [as the following] accomplished as follows.

The representative three-dimensional coordinate (x y z) of the whole link mechanism 1 is defined by the position of the spherical bearing P_1, and at the same time, the direction (angles θ and ϕ of the axial rod R is determined from a motion of the spherical bearing P_2 relative to the spherical bearing P_1.

As the spherical bearing P_2 is driven, it has a relative displacement along of the axial rod R. To allow this displacement, it is necessary that the spherical bearing P_2 can slide along the axial rod R.

Figure 4 is a diagram showing relation of the spherical bearings P_1, P_2 and the axial rod R in terms of their position and direction. The angles ϕ and θ of the polar coordinate system satisfy the following equations: $x' = r \cos \phi \sin \theta$

$$y' = r \sin \phi \sin \theta$$

$$z' = r \cos \theta$$

where

$$x' = x_2 - x_1$$

$$y' = y_2 - y_1$$

$$z' = z_2 - z_1$$

$$r^2 = x'^2 + y'^2 + z'^2$$

wherein

r: distance between P_1 and P_2 on the axis R

x_2: coordinate value of P_2 on the x axis of xyz coordinate

y_2: coordinate value of P_2 on the y axis of xyz coordinate

z_2: coordinate value of P_2 on the z axis of xyz coordinte

x_1: coordinate value of P_1 on the x axis of xyz coordinate

y_1: coordinate value of P_1 on the y axis of xyz coordinate

z_1: coordinate value of P_1 on the z axis of xyz coordinate

θ: angle of R measured from x axis of x-z plane

Φ: angle of R measured from y axis of y-z plane

The length of the axial rod R should be longer than the maximum length of r.

In practice, the width of the spherical bearings P_1 and P_2 along the axial direction is additionally required. If r becomes longer than the length of the axial rod R, the spherical bearing P_2 is dismounted from the axial rod R.

The link mechanism of this invention can be composed from substantially only two spherical bearings and one axial rod. These components can be made of paramagnetic material having small magnetic susceptibility, such as ceramics, glass fiber reinforced material, carbon fiber reinforced material, wood, and non-ferrous metal. Active mechanical elements and sensors are not essential. This link mechanism [can be] has excellent characteristics in MR compatibility, and is readily detachable, cleanable and sterilizable.

USA Patent Application
Kiyoyuki Chinzei
Serial No.: 09/749,125
Filed: December 26, 2000
LINK MECHANISM TO DETERMINE
THE POSITION AND DIRECTION
Examiner: Greg Binda
Group art unit: 3679

MARKED-UP

ABSTRACT OF THE DISCLOSURE

A link mechanism to establish the position of a spherical bearing and the direction of an arm extending from the bearing is provided, which mechanism has a high precision of position and direction determination, does not require strong actuators, and is mechanically ~~simple~~ easy to accommodate MR compatibility, to be cleanable and to be sterilizable. The link mechanism has: an axial rod; and two spherical bearings to support the axial rod, the two spherical bearings being capable of changing relative positions, wherein the motion of one of the two spherical bearings relative to the axial rod along the axis is constrained, and the other of the spherical bearings can travel along the axial rod.